

STRUCTURE, MECHANICAL BEHAVIOR AND NANOINDENTATION OF CHROMIUM AND MOLYBDENUM PRODUCED BY MAGNETRON SPUTTERING

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To clarify the nature of extra-high hardness of fine grain chromium coatings produced by vacuum technology the structure, mechanical behavior and nanohardness of coatings of metals-analogues chromium and molybdenum were studied.

The 80 nm, 400 nm and 2 μ thickness chromium and molybdenum coatings were produced by magnetron sputtering under the same conditions on silicon substrates. The initial pressure in a chamber was about $5 \cdot 10^{-4}$ Pa, after pure argon introduced in the chamber the total argon pressure was 0.3 Pa. The detailed structure investigations were performed by methods of transmission electron microscopy. The mechanical behavior of coatings under point loading conditions was studied by nanoindentation using Berkovich indenter. The image and cross-section of the indentation were investigated by atomic force microscopy (AFM). The nanohardness of chromium and molybdenum coatings was determined by the Oliver and Pharr analysis.

It is shown, that chromium and molybdenum coatings have ultrafine grain structure and characterized by extra-high nanohardness. So, the grains size in 400 nm thickness chromium and molybdenum coatings of are equal to 4–50 nm and 25 nm accordingly. The nanohardness of 400 nm thicknesses chromium coatings is equal to 27 GPa, which is 8-9 times higher than that of monocrystalline chromium (3.6 GPa). At the same time the nanohardness of molybdenum coatings, which were obtained under the same conditions and which characterized even more fine-grain structure, is equivalent to 6 GPa (the nanohardness value of monocrystalline molybdenum is 4.6 GPa). As established, the grain boundaries in chromium and molybdenum coatings are partially amorphous. Comparative analysis of mechanical behavior of chromium and molybdenum coatings showed that chromium coatings have lower plasticity than molybdenum. The plasticity characteristics were calculated using numerical data of load versus indenter displacement for the 400 nm chromium and molybdenum coatings.

The extra-high hardness of chromium coatings cannot be explained only by presence of the nanocrystalline structures or only by presence of interstitial impurities. It is more probable to suppose that hardening of chromium coatings is a result of oxygen atoms embedding in nanocrystals boundaries, i.e. “healing” of defects in weak points on grain boundaries. The important condition for this mechanism is strong chemical bonds existence in the Cr-O system. The polycrystalline chromium is characterized by stronger Me-O bond in comparison with Me-Me connection, in contrast to polycrystalline molybdenum. This mechanism is similar to the mechanism of drastic hardness increasing in nanocrystalline composite materials, which was proposed for multi-component systems by S. Veprek.

Key words: structure, mechanical behavior, nanohardness, chromium, molybdenum, coatings.